Hammerhead Flood Control System Evaluation

Arnon Rosan
Garrison Flood Control

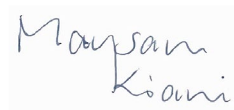
Project ID:	Garrison-0923
Document Name:	Garrison-0923 Hammerhead Flood Control System Evaluation
Date Issued:	October 20, 2023

Predictive Engineering, Inc.
555 MLK Jr Blvd, Suite 105
Portland, Oregon 97214-2120
+1 503.206.5571
www.predictiveengineering.com

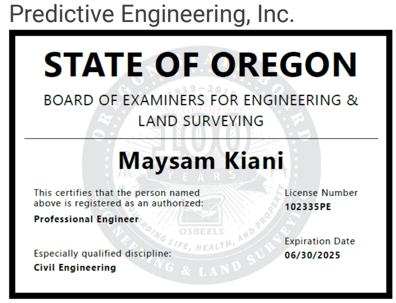
THE ACCURACY AND VALIDITY OF THE FINDINGS ARE A DIRECT RESULT OF THE ACCURACY, CORRECTNESS, AND VALIDITY OF THE DATA PROVIDED BY THE CLIENT. PREDICTIVE ENGINEERING, INC. ASSUMES NO RESPONSIBILITY AND ACCEPTS NO LIABILITY FOR THE CONSEQUENCES OF INCORRECT OR INACCURATE DATA THAT HAD BEEN PROVIDED BY THE CLIENT AND SUBSEQUENTLY USED IN THIS WORK.

RECOMMENDATIONS CONTAINED IN THIS REPORT RELATES ONLY TO THE OPERATING CONDITIONS EXPLICITLY STATED. PREDICTIVE ENGINEERING ASSUMES NO RESPONSIBILITY FOR PROBLEMS THAT MAY ARISE WHEN OPERATING UNDER DIFFERENT CONDITIONS.

Rev	Description of Change	Date Issued	By
0	Engineering Report Released	October 20, 2023	MK



Maysam Kiani, PhD, PE, PMP, PMI-RMP
Principal Mechanical Engineer and
Managing Partner
Predictive Engineering, Inc.


STATE OF OREGON
BOARD OF EXAMINERS FOR ENGINEERING & LAND SURVEYING
Maysam Kiani
This certifies that the person named above is registered as an authorized:
Professional Engineer
License Number
102335PE
Especially qualified discipline:
Civil Engineering
Expiration Date
06/30/2025

Maysam Kiani, PhD, PE, PMP, PMI-RMP
Principal Mechanical Engineer and
Managing Partner
Predictive Engineering, Inc.

Table of Contents

List of Figures

1. OBJECTIVE

The main objective of this project is to capture the plank number limit in various configuration, ensuring the system's robustness and stability. Any system integrated with a plank count below this threshold is deemed to have successfully met the criteria for structural adequacy. Specifically, our study focuses on determining the maximum number of planks permissible in each system without compromising its integrity. The plank widths investigated include 40 inches, 6 feet, and 10 feet, with the established plank number ceiling set at 14. Further detailed examination is given to the 10-foot-wide system in two distinct configurations: the first showcases a center post, while the second incorporates both a center post and a leg support. Figure 1 provide visual representations of the flood control system with a center post and the corresponding leg support anchoring system.

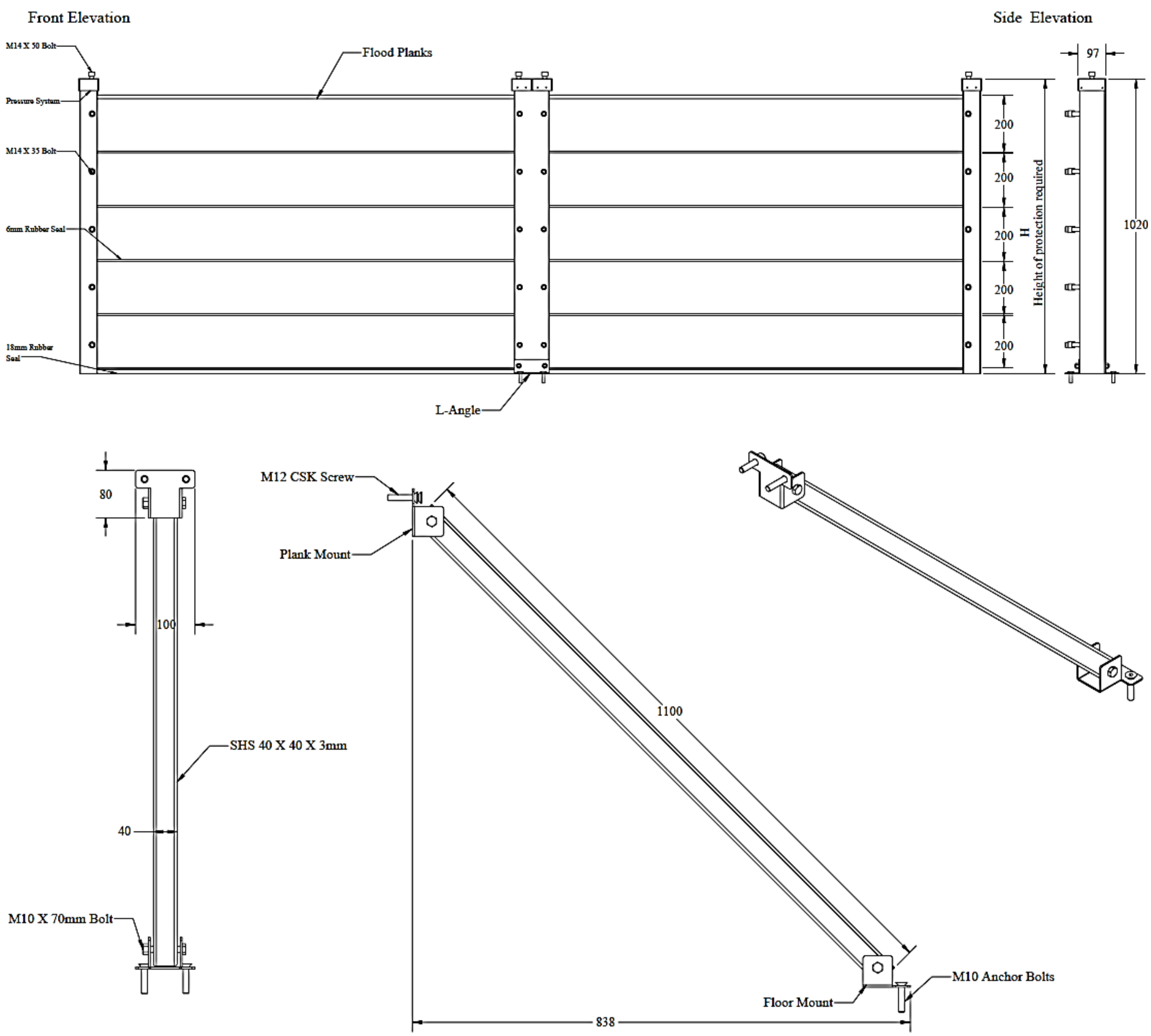


Figure 1: Garrison's Hammerhead Flood Control System with Center Post and Leg Support

2. EXECUTIVE SUMMARY

In our evaluation of flood control systems, we focused on the 'outside mount' configuration due to its previously established significance in Phase 1. For completeness, Table 1 includes data from Phase 1 alongside a summary of our current findings. An essential aspect of our study is the assumption that the water level reaches the maximum height of the planks. Additionally, the conclusions drawn are based on the presence of proper seals and rigid connections, and the effects studied pertain specifically to the hydrostatic load acting on the system. When considering the plank capacity, systems of 40 inches and 6 feet in width can handle up to 14 planks. In contrast, those measuring 10 feet in width are limited to 9 planks. In all these configurations, the maximum stresses were found on the planks.

Introducing a center post into the design shifts the primary stress point to the center post's L-angle connection, accommodating up to 8 planks. When a leg support is added alongside the center post, the main stress moves to the leg support bracket, reducing the plank limit to 7. For systems holding 7 planks or fewer, using both the center post and leg bracket helps distribute stress more uniformly, which in turn strengthens the system by lessening the peak stress on the planks.

Table 1: Summary of Stress Results

Set	Opening Width, mm (ft)	Center Post	Leg Support	Number of Planks	Max. Stress, MPa	Max Stress Location	Result
Phase 1	1,020 (3.33)	No	No	5	23	Plank	pass
	3,050 (10)	No	No	5	112	Plank	pass
1	1,020 (3.33)	No	No	14	40	Plank	pass
	1,830 (6)	No	No	14	116	Plank	pass
	3,050 (10)	No	No	9	130	Plank	pass
2	3,050 (10)	Yes	No	8	201	Center Post L-Angle	pass
3	3,050 (10)	Yes	Yes	7	197	Leg Bracket	pass

3. FEA MODELING

3.1 ENGINEERING UNITS AND SOFTWARE

This analysis is based on the SI system with length as mm's, force as N's, mass as Tonne (kg), time as seconds and temperature as C. In this unit system, the nominal mass density of aluminum is 2.710E-9 Tonne/mm3 with deflections in mm's and stress in MPa. The FE model was built with Femap v2301 MP1 and analyzed with Simcenter Nastran.

3.2 SIGNIFICANCE UNITS

Analysis results are reported to three significant digits and analysis inputs are likewise rounded to three significant digits. Fundamental physical constants are set to four significant digits (e.g., gravity is 9,807 mm/s^2). The imposed limitation on the number of significant digits implies, at best, a relative numerical precision of 1%.

3.3 CAD GEOMETRY

Figure 2 shows the CAD geometry of the system assembly received from Garrison including a reference measurement.

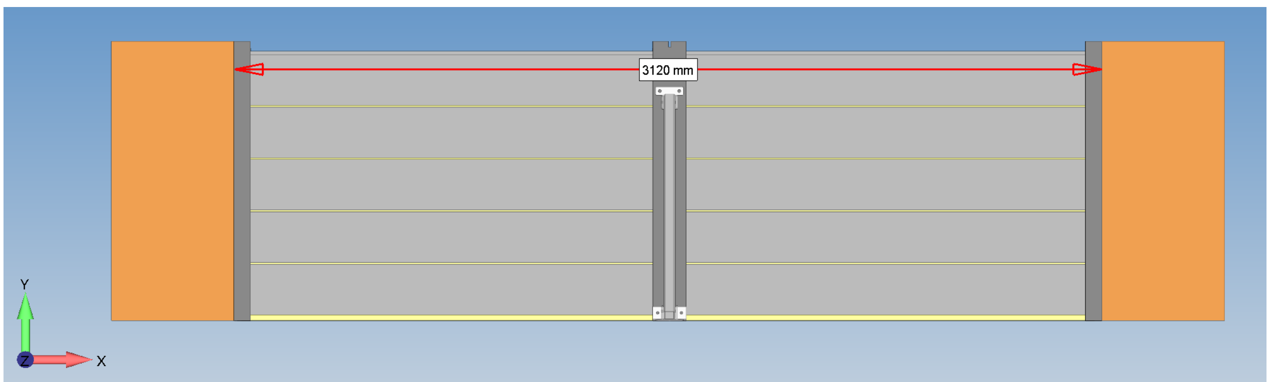


Figure 2: CAD geometry provided by Garrison

3.4 Materials

Table 2 contains a list of the materials used within the model.

Table 2: Analysis Materials

Usage	Material	E, MPa	Poisson's Ratio	Yield Strength, MPa	Ultimate Strength, MPa
Planks	6063-T5 Aluminum	70,000	0.33	145	186
Posts	6063-T5 Aluminum	70,000	0.33	145	186
Rubber Seals	Rubber EPDM	16.50	0.49	-	-
Brackets	304 Stainless Steel	200,000	0.29	215	505
Leg Support	304 Stainless Steel	200,000	0.29	215	505

3.5 FEA Idealization

Figure 3 depicts the FEA idealization of the assembly's CAD geometry. Both planks and posts are represented as plate structures for streamlined analysis.

Planks and posts are idealized into plates

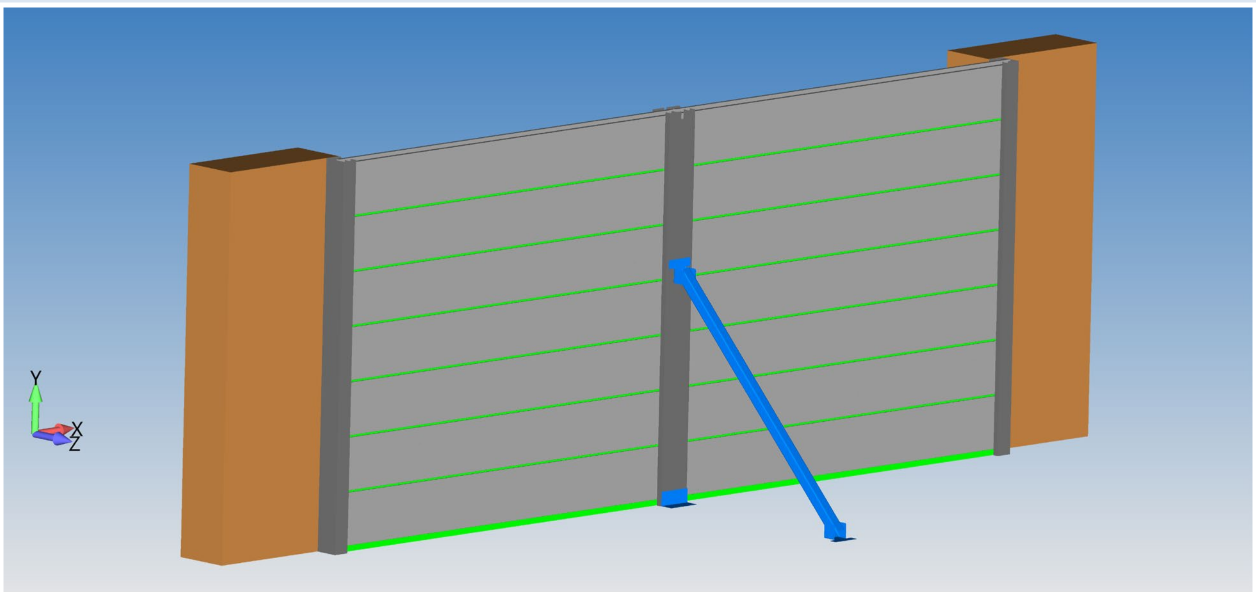


Figure 3: Structural Components for FEA

Figure 4 showcases the FEA idealization of the assembly's CAD geometry, complete with the FEA mesh. The illustration also highlights the planks' tight connection to the center post facilitated by a slide-in plate and rubber seal.

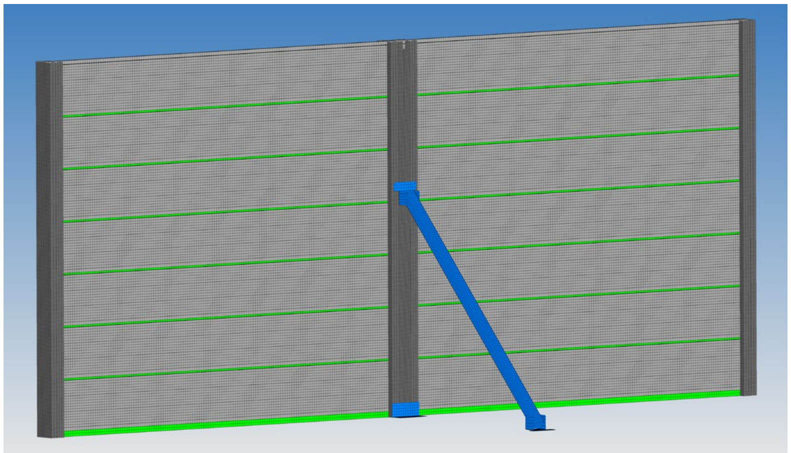
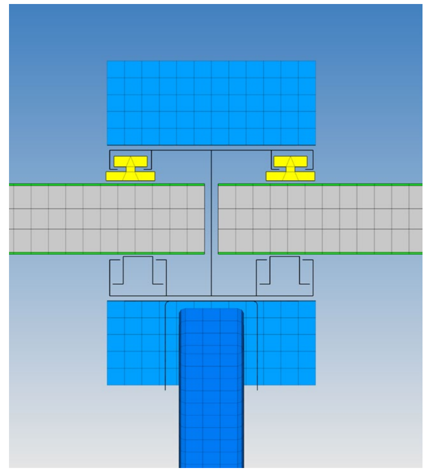
FEA mesh	Planks connection with slide in plate and rubber seal at center post
	

Figure 4: FEA Mesh and Connections

Figure 5 illustrates the boundary conditions as well as the application of hydrostatic load on the system. The system's base is assumed to be firmly anchored to the ground.

Constraints	Hydrostatic Load

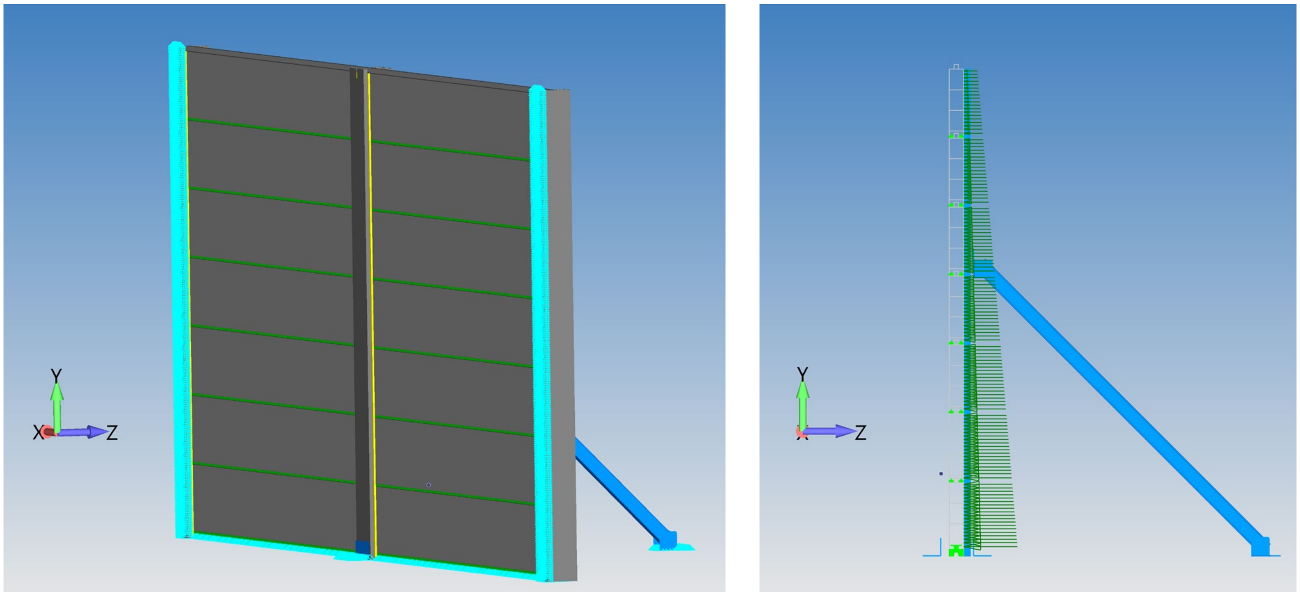


Figure 5: Constraints and Loads

4. FEA SIMULATION RESULTS

4.1 SET 1: STRESS RESULTS FOR NO CENTER POST CASES

4.1.1 1020 MM (40 IN) WIDTH OPENING

Figure 6 shows the von Mises stress of Hammerhead Flood Control Barrier. The maximum von Mises stress is 40 MPa which is lower than the material's yield stress.

Von Mises Stress Contour, MPa

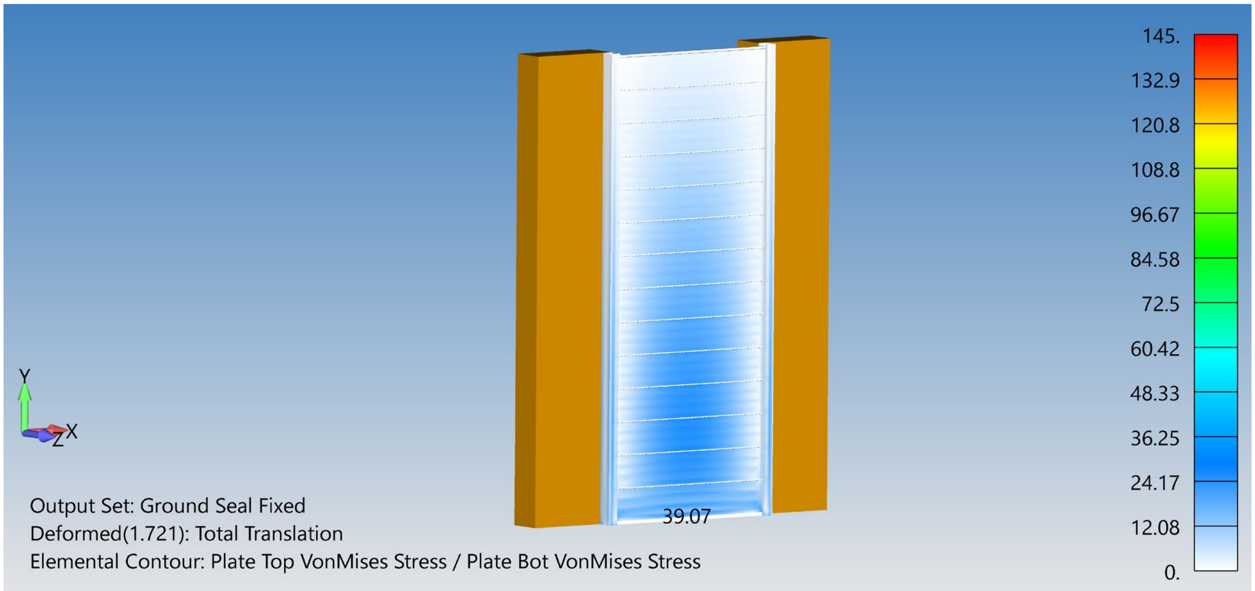


Figure 6: FEA Results for 40-inch Wide 14-Plank tall System

4.1.2 1830 MM (6 FT) WIDTH OPENING

Figure 7 shows the von Mises stress of Hammerhead Flood Control Barrier. The maximum von Mises stress is 116 MPa which is lower than the material's yield stress.

Von Mises Stress Contour, MPa

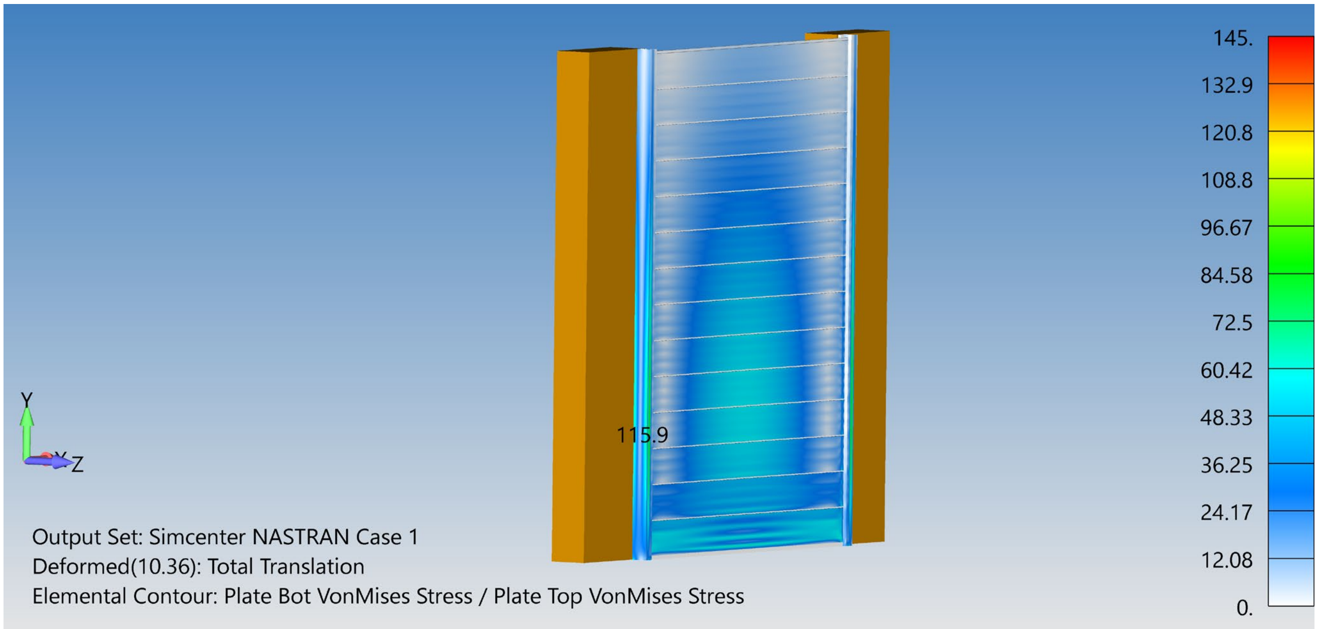


Figure 7: FEA Results for 6-ft Wide 14-Plank tall System

4.1.3 3050 mm (10 ft) Width Opening

Figure 8 shows the von Mises stress of Hammerhead Flood Control Barrier. The maximum von Mises stress is 130 MPa which is lower than the material's yield stress.

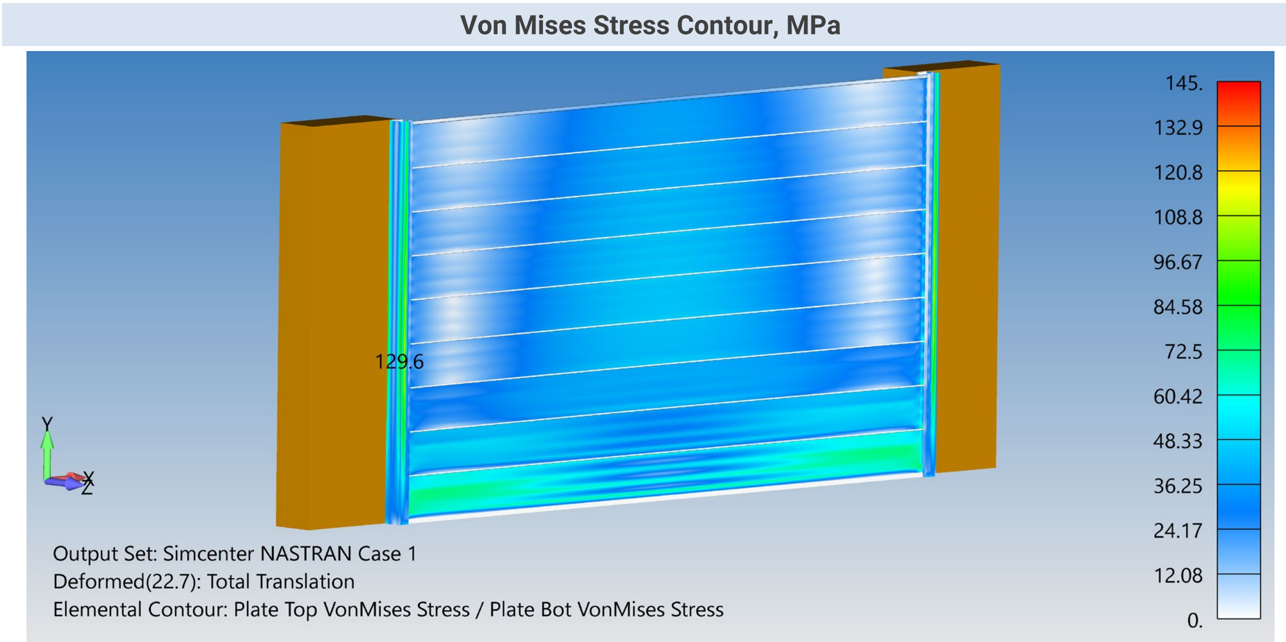


Figure 8: FEA Results for 10-ft Wide 9-Plank tall System

4.2 SET 2: STRESS RESULTS FOR 10 FT WIDE SYSTEM WITH A CENTER POST

Figure 9 shows the von Mises stress of Hammerhead Flood Control Barrier. The maximum von Mises stress is 201 MPa located at the center post L-angle bracket.

Von Mises Stress Contour, MPa

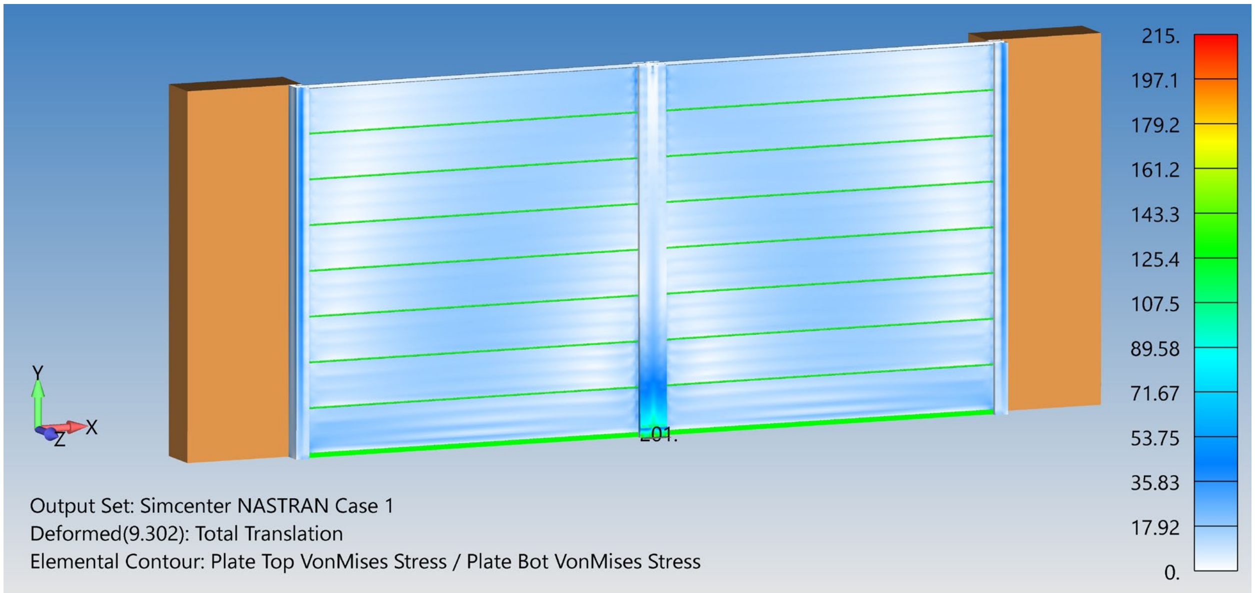


Figure 9: FEA Results for 10-ft Wide 8-Plank tall System with a Center Post

4.3 Set 3: Stress Results for 10 ft wide System with a Center Post and a Leg Support

Figure 10 shows the von Mises stress of Hammerhead Flood Control Barrier. The maximum von Mises stress is 197 MPa located at the leg support bracket connection to the ground.

Von Mises Stress Contour, MPa

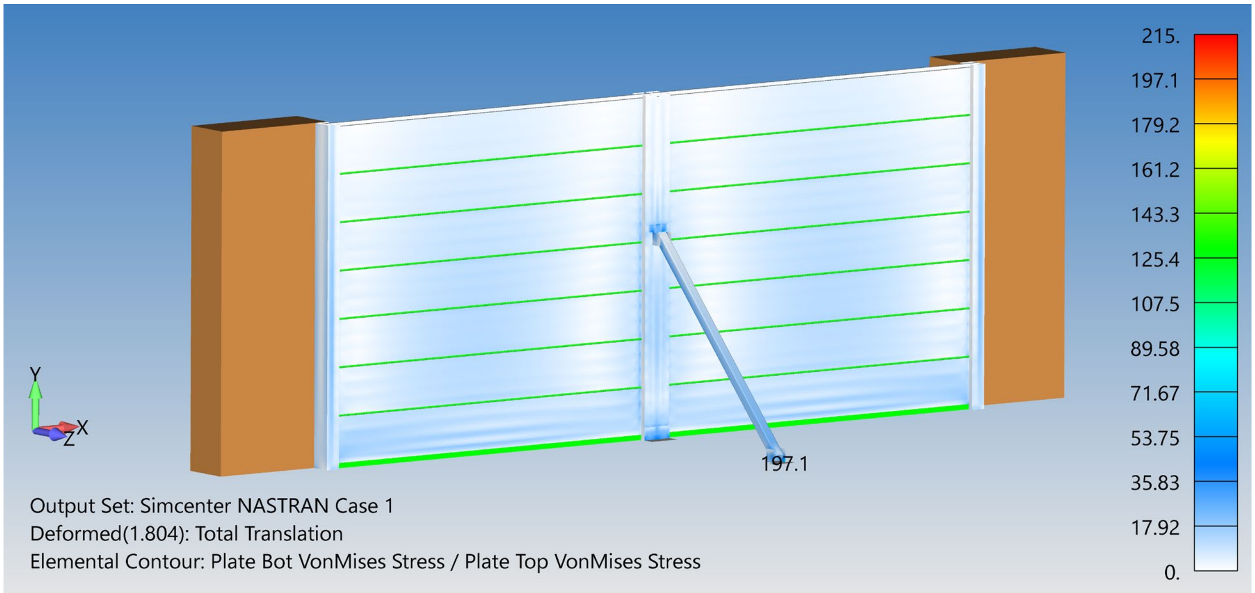


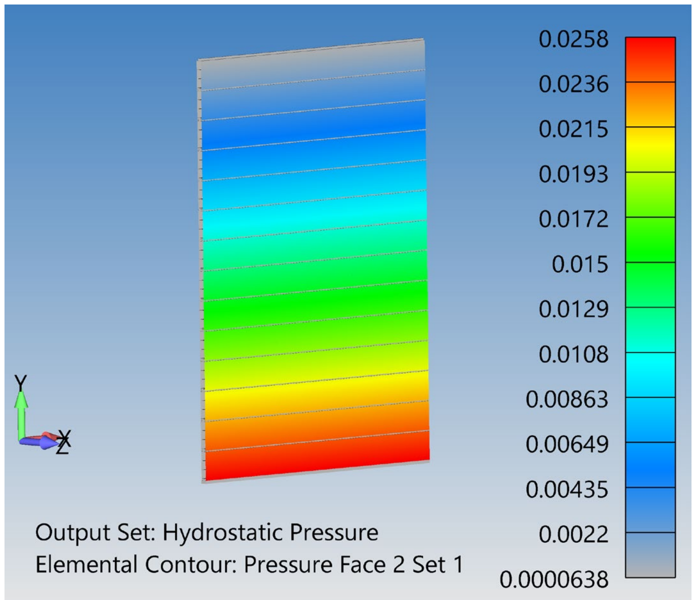
Figure 10: FEA Results for 10-ft Wide 7-Plank tall System with a Center Post and Leg Support

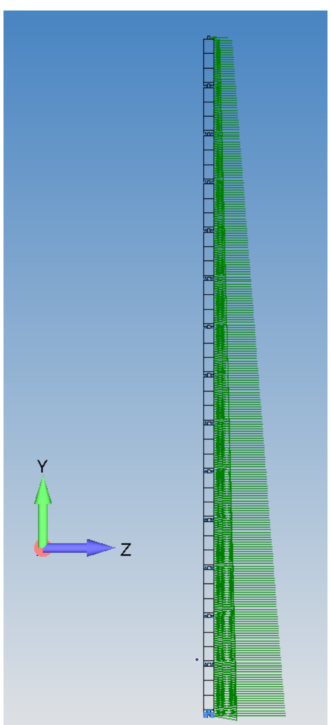
5. APPENDIX

5.1 Load Application Verification

To verify the hydrostatic pressure exerted on the planks in the FE model, we hand-calculated the pressure at the barrier's bottom and the total force on the planks for 1830 mm (6 ft) wide opening with 14 planks stacked. This data was then compared to the information derived from the model for consistency and accuracy.

$$P = \rho g h = 10^{-9} \times 9806 \times 2675 = 0.026\ MPa$$





$$F = \frac{\rho g h}{2} \times h \times w = \frac{10^{-9} \times 9806 \times 2650.78}{2} \times 2650.78 \times 1919 = 66{,}112\ N$$

Check Sum of Forces

```
Summation of Forces, Moments, Pressures and Body Loads for Set 1 (CSys 0)
  Nodal Force                FX =           0.  FY =           0.  FZ =           0.
  Nodal Moment               MX =           0.  MY =           0.  MZ =           0.
  Pressure Force             FX =           0.  FY =           0.  FZ =    -65875.95
  Body Translational Accel   FX =           0.  FY =           0.  FZ =           0.
  Body Varying Trans Accel   FX =           0.  FY =           0.  FZ =           0.
  Body Rotational Accel      FX =           0.  FY =           0.  FZ =           0.
  Body Rotational Velocity   FX =           0.  FY =           0.  FZ =           0.
```